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(71) Applicant: SONY CORPORATION
7-35 Kitashinagawa 6-Chome Shinagawa-ku
Tokyo 141(JP)

(72) Inventor: Tanaka, Masato
c/o Sony Corporation, 7-35, Kitashinagawa
6-chome
Shinagawa-ku, Tokyo(JP)
Inventor: Kan, Toshiya
c/o Sony Corporation, 7-35, Kitashinagawa
6-chome
Shinagawa-ku, Tokyo(JP)

(74) Representative: TER MEER - MÜLLER - STEINMEISTER & PARTNER
Mauerkircherstrasse 45
D-8000 München 80(DE)

(54) **Automatic equalizer.**

(57) An automatic equalizer employed in a recording and/or reproducing apparatus or a transmission channel for a communication system is disclosed wherein equalizer parameters are rendered variable and the degree of the change of the error rate is extracted to set the parameters to optimum values on the basis of the degree of change of the error rate. Output signal error rates are sequentially detected at a plurality of measurement points corresponding to preset plural characteristic parameters to find a minimum error rate measurement point. An initial parameter setting operation is performed of affording the characteristic parameters for this measurement point to the equalizer as the initial parameter.

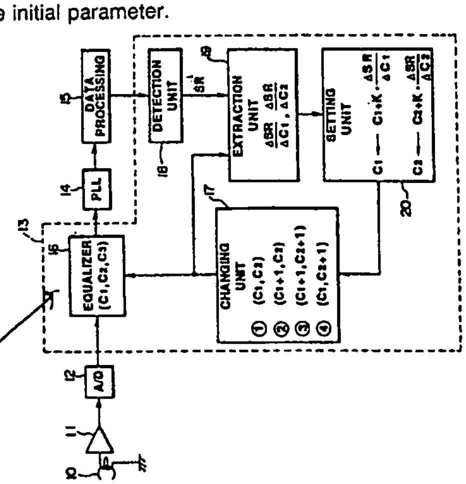

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FIG.5

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Automatic Equalizer

BACKGROUND OF THE INVENTION

Field of Invention

This invention relates to an equalizer employed in, for example, a recording and/or reproducing apparatus or a transmission channel for a communication system. More particularly, it relates to an automatic equalizer in which parameters may be automatically set to optimum values.

Prior Art

In general, in the recording and/or reproducing apparatus or transmission channel for a communication system, an equalizer for affording equalizer characteristics suited to its transmission characteristics to transmission analog or digital signal or data, is employed for diminishing distortion of transmission analog signals or errors in transmission digital data. In magnetic recording and/or reproducing apparatus, such as audio or video tape recorder, an equalizer for affording high-range enhancing characteristics to playback signals by a reproducing magnetic head is provided in the reproducing system for elevating the recording density of the magnetic tape in the recording system.

Conventionally, the properties of the equalizer are adjusted to and fixed at optical values at the time of shipment.

In a rotational magnetic head type video tape recorder or digital audio tape recorder, there is known a system of recording neighboring tracks at different recording azimuth, without providing a guard band, or a so-called inclined azimuth recording, for realizing a high recording density. In a video tape recorder or a digital audio tape recorder employing such inclined azimuth recording system, tracking servo is usually applied for signal reproduction. There is however proposed a signal reproducing apparatus in which, as disclosed for example in the Japanese Patent Publication No. 59-177712 (1984), signal reproduction is performed without tracking servo control.

With such signal reproducing apparatus, first and second inclined tracks TR_A, TR_B are alternately formed at different recording azimuth angles on a magnetic tape 1. For reproducing these tracks, a rotational magnetic head device as shown in Fig. 1 is employed, in which first and second playback rotational magnetic heads 2A, 2B having azimuth angles corresponding to the recording azimuth are mounted at an angular interval of 180° on a tape guide drum 2. Each track of the magnetic tape 1 placed on the tape guide drum 2 over an angular extent of 180° is alternately traced a plural number of times, such as twice, by the first and second playback rotational magnetic heads 2A, 2B. The playback signals obtained by the playback rotational magnetic heads 2A, 2B are supplied, as shown in Fig. 3, from a head changeover switch 31 via playback amplifier 32 and equalizer 33 to signal processing unit 34. The reproduced signals shown in Fig. 4 are produced at an angular interval of 180° from the magnetic heads 2A, 2B by head changeover by the head changeover switch 31 so as to be processed by the signal processing unit 34 to form correct playback signals which are output at a signal output terminal 35.

In magnetic recording and/or reproducing apparatus, the frequency characteristics of the playback system are fluctuated by various factors, such as fluctuations in the magnetic recording media or magnetic heads, changes in temperature or humidity, or temporal changes.

Hence, sufficient operational reliability cannot be obtained with the use of the conventional equalizer with fixed equalizer characteristics. On the other hand, adjustment with an allowance in the equalizer characteristics to take account of fluctuations in the playback system results in the lowering of the recording density corresponding to such preset allowance.

On the other hand, with a signal reproducing apparatus in which signal reproduction is performed without tracking servo, each track on the magnetic tape is traced alternately by the first and second playback magnetic heads 2A, 2B for complete tracing, so that the track-tracing relation is such that each track corresponds to two tracing. In other words, the track-tracing relation is the same for every other head tracing but differs for two consecutive head tracing.

Hence, in the reproducing apparatus in which signal reproduction is performed without tracking control, equalizing characteristics for odd-numbered tracing need be measured and set independently from those for even-numbered tracing and, for implementing such function of equalization, the overall system cannot

but be complicated.

Summary of the Invention

It is an object of the present invention to provide an improved automatic equalizer.

It is another object of the present invention to provide an automatic equalizer in which the characteristic parameters can be efficiently and reliably converged into optimum values to afford optimum equalizer characteristics to the input signal.

It is a further object of the present invention to provide a signal reproducing apparatus adapted to reproduce signals without tracking, wherein automatic setting of equalizing characteristics can be realized by a simplified arrangement.

It is a further object of the present invention to provide a signal reproducing apparatus having an automatic equalizing function of efficiently extracting changes caused in the degree of the effect of the characteristic parameters of the equalizer between odd-number tracing and even-number tracing.

The above and other objects as well as novel features of the present invention will become apparent upon reading the following description in conjunction with the accompanying drawings and the novel matter pointed out in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows the relation between the recording track and the reproducing magnetic head in the digital audio tape recorder of the inclined azimuth recording system.

Fig. 2 is a diagrammatic plan view showing the construction of a rotational magnetic head device employed in the digital audio tape recorder.

Fig. 3 is a block diagram showing the construction of the conventional digital audio tape recorder.

Fig. 4 shows reproduced output signals from the reproducing magnetic heads in the conventional digital audio tape recorder shown in Fig. 3.

Fig. 5 is a block diagram showing a first embodiment of the automatic equalizer according to the present invention.

Fig. 6 is a block diagram showing an embodiment of an equalizer employed

Fig. 7 illustrates the state of change of the equalizer parameters with the aid of a coordinate system.

Fig. 8 illustrates characteristic parameters for elucidating the problems inherent in the automatic equalizer with the aid of a two-dimensional coordinate system.

Fig. 9 is a block diagram showing a second embodiment of an automatic equalizer of the present invention when applied to a digital audio tape recorder.

Fig. 10 illustrates characteristic parameters for elucidating the operation of the initial parameter setting unit of the automatic equalizer.

Fig. 11 is a flowchart for elucidating the operation of the automatic equalizer.

Fig. 12 is a block diagram showing a functional example of the characteristic parameter control unit of the automatic equalizer.

Fig. 13 illustrates characteristic parameters for elucidating the control operation by the characteristic parameter control unit with the aid of a two-dimensional coordinate system.

Fig. 14 is a block diagram showing the construction of a reproducing system of a digital audio tape recorder to which the present invention is applied.

Fig. 15 illustrates characteristic parameters for illustrating the operation of the automatic equalizer used in the reproducing system shown in Fig. 14 with the aid of the two-dimensional coordinate system.

EMBODIMENTS

Referring to the drawings, certain preferred embodiments of the present invention will be explained in detail.

Fig. 5 shows an application of the automatic equalizer of the present invention to a transmission circuit or channel of a reproducing system of a signal recording and/or reproducing apparatus.

In Fig. 5, playback RF signals, reproduced from a magnetic recording medium by a playback head 10, are transmitted via amplifier 11 to an analog-to-digital (A/D) converter 12 where they are converted into digital signals, which are transmitted to an automatic equalizer 13. Equalized digital signals are output from

the equalizer 13 and transmitted to a data processing circuit 15 by way of a phase locked loop (PLL) circuit 14.

The automatic equalizer 13 is constituted by an equalizer 16, interposed between the A/D converter 12 and the PLL circuit 14, and a changing unit 17, a detection unit 18, an extraction unit 19 and a setting unit 20 for setting parameters for equalizer 16.

The equalizer 16 is an FIR type digital filter having its characteristics controlled by three parameters C_1, C_2 and C_3, and affords equalizing characteristics consistent with the parameters C_1, C_2 and C_3 to digital signals supplied from the A/D converter 12 to transmit the resulting signals to the PLL circuit 14.

The equalizer 16 may be arranged as shown in Fig. 6, wherein a digital signal supplied to input terminal 21 is supplied to first multiplier 24, while being supplied via delay elements 22, 23 to second and third multipliers 25, 26, respectively, and wherein the signals are weighted in accordance with the parameters C_1, C_2 and C_3 in these multipliers 24, 25 and 26 and summed at a summing point 27 before being output at an output terminal 28.

With the above described automatic equalizer 13, of the parameters C_1, C_2 and C_3, determining the characteristics of the equalizer 16, the parameter C_3 is always fixed at a predetermined level, whereas the parameters C_1 and C_2 are variable. These parameters C_1 and C_2 are changed in dependence upon the outputs from the changing unit 17.

The changing unit 17 acts for changing the parameters C_1 and C_2, set in the setting unit 20, as will be explained subsequently, within a predetermined small extent, at a predetermined short interval of time, with the thus changed parameters being supplied as the parameters C_1 and C_2 of the equalizer 16. For changing the parameters C_1 and C_2 in this manner, a parameter (C_1, C_2) set by the setting unit 20, hereinafter referred to as value (i) is changed to (C_1+1, C_2), hereinafter referred to as value (ii), then to (C_1+1, C_2+1), hereinafter referred to as value (iii) and then to (C_1, C_2+1), hereinafter referred to as value (iv), as shown by a coordinate system in Fig. 7. The parameters are repeatedly cycled in the range of the values (i) to (iv) in a manner of orthogonal oscillation by a predetermined amount around the value (i) for utmost effect for high speed operation.

When supplied with the value (i) to (iv) as the parameters C_1 and C_2, the equalizer 16 performs a corresponding equalizing operation on the digital signal before transmitting the signal via PLL circuit 14 to the data processing circuit 15. A portion of the digital signal, transmitted to the data processing circuit 15, is retransmitted to the detection unit 18 of the automatic equalizer 13.

The detection unit 18 detects the error rate of the digital signal from the data processing circuit 15 to form a data SR indicating the detected error rate, which data SR is transmitted to the extraction unit 19.

The extraction unit 19 is supplied with the data indicating the values (i) to (iv) from the changing unit 17 and fetches the error rate data SR for the values (i) to (iv) to detect the error rates SR(i) to SR(iv) for the values (i) to (iv). From these results, the ratio of change of the error rate to the variance in the parameter C_1 or$\Delta sR/\Delta C_1$ is extracted by an equation

$$\frac{\Delta SR}{\Delta C_1} = \frac{(SR(ii) + SR(iii)) - (SR(i) + SR(ii))}{2} \quad \cdots\cdots (1)$$

while the ratio of change of the error rate to the variance of the parameter C_2 or $\Delta SR/\Delta C_2$ is extracted by an equation

$$\frac{\Delta SR}{\Delta C_2} = \frac{(SR(iii) + SR(iv)) - (SR(i) + SR(ii))}{2} \quad \cdots\cdots (2)$$

The data indicating these change ratios are supplied to the setting unit 20, which adds a correction value $K \cdot \Delta SR/\Delta C_1$ to the preceding value C_1 in accordance with an equation

$$C_1 = C_1 + K \cdot \frac{\Delta SR}{\Delta C_1} \quad (3)$$

where K is a constant of proportionality, to compute a new value of the parameter C_1 for the equalizer 16 so as to diminish the error rate, while adding a correction value $K \cdot \Delta SR/\Delta C_2$ to the preceding value C_2 in accordance with an equation

$$C_2 = C_2 + K \cdot \frac{\Delta SR}{\Delta C_2} \quad (4)$$

where K is a constant of proportionality, to compute a new value of the parameter C_2 for the equalizer 16 so as to diminish the error rate. The operation of computing new values for the parameters C_1 and C_2 need not be linear but may also be non-linear, on the condition that satisfactory characteristic may thereby be produced.

The new values of the parameters C_1 and C_2 thus set are applied to the changing unit 17 which change these new parameter C_1 and C_2 as described above to transmit the thus changed values to the equalizer 16.

The above sequence of operations is repeated by the above units 16 to 20 in the automatic equalizer 13 to change the parameters C_1 and C_2 of the equalizer 16 automatically for reducing the output error rate of the equalizer 16. Ultimately, automatic setting is so made as to minimize the error rate, that is to optimize the parameters C_1 and C_2 for the equalizer 16.

In addition, since the parameters C_1 and C_2 of the equalizer 16 of the automatic equalizer 13 are set in accordance with the extent of change of the error rate, as described above, the automatic equalizer may be implemented with a simple circuit organization, as that the system may be reduced in size and costs. Moreover, since the parameters C_1 and C_2 of the equalizer 16 can be computed by a simplified operation, optimum values of the parameters may be found by convergence at a higher speed.

Although the automatic equalizer 16 operating on a digital signal has been explained in the foregoing, an automatic equalizer operating on an analog signal may also be implemented by detecting the error rate of the output of an analog equalizer by, for example, digital signal processing.

With the above described first embodiment of the present invention, the equalizer parameters may be automatically set to optimum values so as to follow fluctuations in characteristics caused by changes in the environment and to automatically cope with temporal changes in the circuitry as well as fluctuations or changes in the recording medium. In this manner, with the use of the above described automatic equalizer 16, a system can be implemented which is excellent both in interchangeability and in operational reliability.

The equalizer parameters are set as a function of the degree of changes in the error rate, so that the circuit construction may be simplified to reduce the size and costs of the system.

Moreover, the equalizer parameters can be computed by a simplified operation, so that convergence to optimum values of the parameters may be achieved within a shorter period of time.

Above all, the optimum parameters may be set at an elevated speed by employing the parameter changing method of orthogonally oscillating the parameters.

However, with the above described first embodiment of the automatic equalizer 16, prolonged convergence time is necessitated when the initial value of the equalizer parameter is markedly different from the convergence value. On the other hand, assuming that, in a multidimensional space that can be occupied by the values of the characteristic parameters, a spatial area exists in which the signal error rate of the equalizer output is constant, that is, the change in the signal error rate is zero, and that the above mentioned minute change area of the characteristic parameters is included in the spatial area, it becomes impossible to converge the characteristic parameters to an optimum value. For example, as shown in Fig. 8, showing the signal error rate of the equalizer output by contour lines, when a region with a constant signal error rate of the equalizer output "1" exists, as shown by hatched lines therein, in a twodimensional plane that can be occupied by the equalizer characteristic parameters C_1 and C_2, the above mentioned characteristic values cannot be controlled in a direction of approaching towards an optimum value even when the signal error rate is detected at each of measurement points P_1, P_2, P_3 and P_4 in the above region with changed characteristic parameters, since the change in the signal error rate is unexceptionally "0".

With the automatic equalizer with variable characteristic parameters, initial parameters are afforded by initial parameter setting means to variably control the characteristic parameters by characteristic parameter control means.

For each of the measurement points, corresponding to a plurality of previously set characteristic values, the above mentioned parameter setting means sequentially detects the signal error rate of the equalizer output by error rate detection means to find a minimum error rate measurement point to afford the characteristic parameters of the thus found measurement point to the equalizer as the initial parameters.

The characteristic parameter control means repeatedly performs a control operation of changing characteristic parameters of the equalizer within a predetermined range and variably controlling, on the basis of the degree of change of the signal error rate of the equalizer output detected by the error rate detection means, the equalizer characteristic parameters in a direction of diminishing the signal error rate.

Fig. 9 shows, in a block diagram, the organization of a playback system of a digital audio tape recorder employing an automatic equalizer according to a second embodiment of the present invention.

The playback system shown in Fig. 9 is provided with a magnetic head 31 for reproducing digital audio data recorded on a magnetic tape 30. The playback signal reproduced by the magnetic head 31 from the magnetic tape 30 is supplied to an analog to digital (A/D) converter 33 by way of a playback amplifier 32. The A/D converter 33 converts the playback signal into binary values and thereby into a corresponding digital signal. The digital signal obtained by the A/D converter 33 is supplied by way of an equalizer 37 to a data processing unit 35, when performs prescribed error correction or decoding operations on the digital signal supplied over the equalizer 37. The data processing unit 35 decodes digital audio data from the digital signal to output decoded data as playback audio data at a signal output terminal 36.

With the playback system, the equalizer 37 constitutes automatic equalizer 34 and has variable equalizer characteristics by virtue of the three characteristic parameters C_1, C_2 and C_3 supplied from a characteristic parameter setting unit 38.

The equalizer 37 is constructed similarly to the equalizer shown in Fig. 6.

As shown in Fig. 9, the automatic equalizer 34 is constituted by the equalizer 37 having variable equalizer characteristics by virtue of the three characteristic parameters C_1, C_2 and C_3 supplied from the characteristic parameter setting unit 38, an error rate detection unit 39 for detecting a signal error rate of the output from this equalizer 37, an initial parameter setting unit 40 for affording initial value of the parameter C_1 to C_3 of the equalizer 37, or initial parameters, to the parameter setting unit 38, on the basis of the signal error rate ER detected by the error rate detection unit 39.

With the above described automatic equalizer 34, of the characteristic parameters C_1 to C_3 afforded by the parameter setting unit 38 to the equalizer 37, the third parameter C_3 is always fixed at a predetermined level, while the first and the second parameters C_1 and C_2 are variably set for affording an optimum equalizer output by the equalizer 37.

The initial parameter setting unit 40 performs, in a sequence shown in a flow chart of Fig. 11, a setting operation in which, in a two-dimensional plane that can be occupied by first and second characteristic parameters C_1 and C_2 of the equalizer 37, the signal error rates ER of the output of the equalizer 37 are sequentially detected by the error rate detection unit 39 at a necessary minimum number of present measurement points A, B, C, D, E and F thought to be excellent as the initial values of the characteristic parameters C_1 and C_2 as shown in Fig. 10, to find a measurement point of the minimum error rate ER_{MIN} for affording the characteristic parameters C_1, C_2 of the thus found measurement point to the setting unit 38 as the initial parameters.

On starting the operation of the automatic equalizer 34, the initial parameter setting unit 40 sets a variable N which counts the number of the measurement points A, B, C, D, E and F to 1 at first step S_1, and then proceeds to next step S_2.

In this second step S_2, it is determined if the mode is the search mode of setting the initial parameter. If the result is NO, that is, if the mode is not the search mode, the program proceeds to an undermentioned step S_{12}. If the result of decision at step S_1 is YES, that is if the mode is the search mode, the program proceeds to the next third step S_3.

On starting the operation of the automatic equalizer 34, the above mentioned search mode is set, and the program processed from second step S_2 to third step S_3.

In this third step S_3, it is determined if the signal error rate ER of the output of the equalizer 37 currently detected by the error rate detection unit 39 is larger than a predetermined value k_1. If the result of decision at the third step S_3 is NO, that is if the signal error rate ER is smaller than the predetermined value k_1, the program proceeds to the undermentioned step S_9. If the result of decision at the third step S_3 is YES, that is if the signal error rate ER is larger than the predetermined value k_1, the program proceeds to the next fourth step S_4.

In this fourth step S_4, the characteristic parameters C_1 and C_2 at the first measurement point A, indicated by the variable N (N = 1), are afforded to the parameter setting section 11, and the signal error rate ER of the output of the equalizer 37 is detected by the error rate detection unit 39.

At the next step S_5, the variable N is incremented, after which the program proceeds to the step S_6.

At the step S_6, it is determined if the signal error rate ER has been detected for all of the measurement points A to F. If the result of decision at the sixth step S_6 is NO, the program reverts to the second step S_2 to repeat the operation from step S_2 to step S_6. In this manner, the signal error rate ER is detected for the measurement points A to F in this order. If the result of decision at the sixth step S_6 is YES, that is if the signal error rate ER has been detected for all of the measurement points ER, the program proceeds to the next seventh step S_7.

At this seventh step S_7, it is determined if the minimum value ER_{MIN} of the signal error rates detected for the measurement points A to F is smaller than the predetermined value k_2. If the result of decision at the seventh step S_7 is NO, that is if the minimum error rate value ER_{MIN} smaller than the predetermined value

k_2 cannot be obtained, it is concluded that the detection of the signal error rates ER for the measurement points A to F by the processing operation from second step S_2 to sixth step S_6 has resulted in failure. Thus, at step S_8, the variable N is set to 1 and the program reverts to the second step S_2 to repeat the operation of detecting the signal error rate ER. If the result of decision at the seventh step S_7 is YES, that is if the minimum error rate ER_{MIN} smaller than the predetermined value k_2 is found, the program proceeds to the ninth step S_9.

At this ninth step S_9, a stationary mode is set as the operating mode of the automatic equalizer 34.

At the next step S_{10}, the initial parameters having as the initial values the values of the characteristic parameters C_1 and C_2 for the measurement point for which the minimum error rate ER_{MIN} has been obtained by the search mode operation, for example, the fourth measurement point D shown in Fig. 10, are afforded to the characteristic parameter setting section 38.

After affording the initial parameters to the parameter setting unit 38, the initial parameter setting unit 40 causes the control of the parameter setting section 38 to be taken charge of by parameter control unit 41.

If the result of decision at the above mentioned third step S_3 is NO, that is if the measurement point for which the signal error rate ER becomes smaller than the predetermined value k_1, the initial parameter setting unit 40 proceeds to step S_9 to set the stationary mode. At the tenth step S_{10}, the initial parameters having as the initial values the values of the characteristic parameters C_1 and C_2 at the measurement points for which the signal error rate ER detected by the decision operation at the third step S_3 becomes smaller than the predetermined value k_1, are afforded to the characteristic parameter setting unit 38. In this manner, at a time point when the measurement point has been found for which the signal error rate ER is smaller than the predetermined value k_1, initial parameters having the values of the characteristic parameters C_1 and C_2 for the measurement point as the initial values are set to expedite the operation for the search mode.

The characteristic parameter control unit 41 performs the stationary mode control operation at the eleventh step S_{11}, and is organized as shown for example in Fig. 12. Thus the characteristic parameter control unit 41 is constituted by a control unit 42 for sequentially changing the characteristic parameters C_1 and C_2 afforded by the parameter setting unit 38 to the equalizer 37 at a predetermined short time interval within a predetermined minute range, a computing unit 43 for computing the degree of change of the signal error rate ER detected by the error rate detection unit 39, and a setting unit 44 for setting the characteristic parameters C_1 and C_2 of the equalizer 37 in the direction of the decreasing error rate ER on the basis of the degree of change of the error rate ER computed by the computing unit 43.

The control unit 42 performs a control operation of minutely orthogonally oscillating the values of the characteristic parameters C_1 and C_2 in the sequence of $P_1(C_1,C_2) \rightarrow P_2(C_1+1,C_2) \rightarrow P_3(C_1+1,C_2+1) \rightarrow P_4(C_1,C_2+1)$, as shown in Fig. 13, in a two-dimensional plane which can be occupied by the values of the characteristic parameters C_1 and C_2 afforded by the characteristic parameter setting unit 38 to the equalizer 37.

The computing unit 43 operates on the output from the equalizer 37 for the characteristic parameters of the values $P_1(C_1,C_2)$, $P_2(C_1+1,C_2)$, $P_3(C_1+1,C_2+1)$ and $P_4(C_1,C_2+1)$ to compute the degree of change $\Delta ER/\Delta C_1$ of the variance Δ ER of the error rate ER with respect to the variance ΔC_1 of the first parameter C_1, in accordance with the equation (5)

$$\frac{\Delta ER}{\Delta C_1} = \frac{(ER_2 + ER_3) - (ER_4 + ER_1)}{2} \quad \ldots\ldots (5)$$

while simultaneously computing the degree of change $\Delta ER/\Delta C_2$ of the variance ΔER of the error rate ER with respect to the variances ΔC_2 of the second characteristic parameter C_2, in accordance with the equation (6)

$$\frac{\Delta ER}{\Delta C_2} = \frac{(ER_3 + ER_4) - (ER_1 + ER_2)}{2} \quad \ldots\ldots (6)$$

The data of the degrees of change $\Delta ER/\Delta C_1$, $\Delta ER/\Delta C_2$ of the variance ΔER of the error rate ER will respect to the variances ΔC_1, ΔC_2 of the characteristic parameters C_1, C_2, computed by the unit 43, are

supplied to the setting unit 44.

On the basis of the ratio data $\Delta ER/\Delta C_1$, $\Delta ER/\Delta C_2$ of the variance ER of the error rate ER with respect to the variance ΔC_1, ΔC_2 of the above mentioned characteristic parameters C_1 and C_2, the setting unit 44 sets the new values of the characteristic parameters C_1, C_2 in the following manner to diminish the error rate ER.

Thus the setting section 44 sets a new value of the first characteristic parameter C to

$$C_1 + K \cdot \frac{\Delta ER}{\Delta C_1}$$

which is the value of the preceding first characteristic parameter C_1 added to by a correction value $K \cdot \Delta ER/\Delta C_1$. The setting section 44 also sets a new value of the second characteristic parameter C_2 to

$$C_2 + K \cdot \frac{\Delta ER}{\Delta C_2}$$

which is the value of the preceding second characteristic parameter C_2 added to by a correction value $K \cdot \Delta ER/\Delta C_2$. In the above formulae, K stands for a proportionality constant.

The setting operation of the new characteristic parameters C_1 and C_2 by the setting unit 44 need not necessarily be a linear operation, but may also be a nonlinear operation, if the error rate ER may thereby be reduced effectively.

The new characteristic parameters C_1 and C_2, thus set by the setting unit 44, are afforded to the control unit 42, which then repeatedly performs the control operation of minutely orthogonally oscillating these new characteristic parameters C_1 and C_2.

In this manner, the characteristic parameter control unit 41 causes the characteristic parameters C_1 and C_2 of the equalizer 37 to be changed within a predetermined range and, on the bases of the extent of the variance ER of the signal error rate ER detected by the error rate detection unit 39, repeatedly performs an operation of variably controlling the characteristic parameters C_1 and C_2 of the equalizer 37 in the direction of diminishing the error rate ER for automatically controlling the characteristic parameter C_1 and C_2 of the equalizer 37 to the state of the minimum signal error rate ER.

The characteristic parameter control unit 41 performs a control operation for the characteristic parameters C_1 and C_2, using the characteristic parameters C_1 and C_2 for the fourth measurement point D, afforded as the initial parameters by the initial parameter setting unit 40, as the initial values.

In this manner, the characteristic parameters C_1, C_2 can be converged to optimum values promptly and reliably.

In the present embodiment, the program reverts to the above mentioned second step S_2, each time the characteristic parameter control unit 41 performs a control operation for the characteristic parameters C_1, C_2, that is the control operation of the stationary mode of the eleventh step S_{11}, while reverting to the step S_{12} from the step S_2 during the control operation of the stationary mode, in order to decide if the signal error rate ER obtained by the error detection unit 39 is larger than a predetermined value k_3.

If the result of decision at the twelfth step S_{12} is NO, that is if the signal error rate ER is lesser than the value k_3, the program reverts to the eleventh step to repeat the stationary mode control operation.

If the result of decision at the twelfth step S_{12} is YES, that is if the error rate ER is larger than the predetermined value k_3, the program proceeds to the next thirteenth step S_{13}.

In this thirteenth step S_{13}, it is determined if the number of times n the error signal rate ER is larger than the predetermined value k_3 is larger than a predetermined value k_4. If the result of decision at step S_{13} is NO, the program reverts to the eleventh step S_{11} to repeat the stationary mode control operation. If the result of decision at the step S_{13} is YES, that is if the state in which the signal error rate ER is larger than the predetermined value k_3 occurs on end by a predetermined number of times k_4, the program proceeds to the next fourteenth step S_{14} for setting the measurement point P_0 indicated by the characteristic parameters C_1 and C_2 at this time as the even-numbered-ruple measurement point, while simultaneously setting the search mode.

After setting the variable N to 1 at the next step S_{15}, the program reverts to the above mentioned fourth step S_2 to proceed to the above mentioned search mode.

When the state in which the signal error rate ER is larger than the predetermined value k_3 occurs on end for a predetermined number of times k_4 during the above mentioned ordinary operational mode, and the mode shifts to the above mentioned search mode, the processing operation from the step S_2 to the step S_6 is repeated, and each signal error rate ER is sequentially detected for each of the measurement point P_0 set at the step S_{14} and the preset measurement points A to F, in the order of $A \rightarrow P_0 \rightarrow B \rightarrow P_0 \rightarrow C \rightarrow P_0 \rightarrow D \rightarrow P_0 \rightarrow E \rightarrow P_0 \rightarrow F$, for performing the above mentioned search operation.

After setting the new initial parameter by the above search operation at the tenth step S_{10}, the program reverts to the eleventh step S_{11} to reinitiate the above mentioned control operation for the stationary mode.

If the signal error rate ER of the measurement point P_0 is equal to the minimum error rate ER_{MIN} of the measurement points A to F, the characteristic parameters C_1 and C_2 of the measurement point PO are preferentially set as the above mentioned initial parameters. The decision values k_1, k_2 and k_3 of the signal error rate ER at the steps S_2, S_7 and S_{12} are set so that the relation
$k_1 < k_2 < k_3$ or $k_1 < k_3 < k_2$
is satisfied.

With the above described record embodiment of the automatic equalizer according to the present invention, the characteristic parameters of that measurement point among those corresponding to preset plural characteristic parameters which gives the smallest signal error rate, are afforded as the initial parameters by initial parameters setting means to the equalizer having variable characteristic parameters, so that the control operation of converging the characteristic parameters of the equalizer to an optimum value by characteristic parameter control means may be started at a point closer to the above mentioned optimum value. Also, since the initial parameter setting means detects the signal error rate of the equalizer output for each of the measurement points corresponding to the plural characteristic parameters, the initial parameters can be set which will allow the characteristic parameters to be converged efficiently and reliably to an optimum value by the above mentioned parameter control means. In this manner, the characteristic parameters can be converged to optimum values efficiently and reliably by the above characteristic parameter control means. In addition, the initial parameter setting means affords a measurement point not higher than the preset signal error rate to the equalizer as the initial parameter, at the time when such measurement point is found, so that the initial parameter setting operation may be performed expeditiously. Also, when the signal error rate of the equalizer exceeds a preset signal error rate during the characteristic parameter control operation by the parameter control means, the initial parameter setting means performs an operation of setting the initial parameters, using the characteristic parameters in this state as one of the plural measurement points, so that the initial parameter setting operation may be performed expeditiously.

In this manner, there is provided an automatic equalizer in which the characteristic parameters of the equalizer may be converged efficiently and reliably to an optimum values to afford the optimum equalizer characteristics to input signals.

Meanwhile, in a signal reproducing apparatus in which signal reproduction is performed without tracking control, as disclosed in the above mentioned Japanese Patent Application No. 59-177712 (1984), each track of the magnetic tape is traced completely only by alternately tracing the track by two magnetic heads so that the track-tracing correlation exhibits a 2-tracing-per-track periodicity. Thus the track-tracing correlation remains constant between every other head-tracing but differs between two consecutive head-tracings.

Thus, when applying the automatic equalizer to the reproducing apparatus, it is necessary to perform the measurement of the effect of the characteristic parameters of the equalizer at the odd-number-ruple tracing and that at the even-number-ruple tracing separately, so that the overall system becomes complex and bulky in size, while its costs, weight and power consumption are necessarily increased.

The present invention contemplates to apply the above mentioned automatic equalizer to the signal reproducing apparatus performing signal reproduction without tracking control to simplify the overall system while reducing its weight, cost and power consumption, and is directed to a signal reproducing apparatus having an automatic equalizing function of efficiently extracting changes in the degree of effect of the characteristic parameters of the equalizer in an odd-number-ruple tracing and an even-number-ruple tracing.

With the signal reproducing apparatus of the present invention, reproduction outputs from the first and second playback rotational magnetic heads are converted into a binary form by a binary unit, and equalizer characteristics are afforded to the binary output from the binary unit by an equalizer having variable characteristic parameters, with the equalized output from the equalizer being then decoded by decoding means into digital signals.

The error detection means detects the signal error rate of the decoded output by the decoding means, that is the digital signal obtained upon decoding by the decoding means.

The characteristic parameter control means repeats a control operation of orthogonally allocating the characteristic parameters of the equalizer in an orthogonal relation which eliminates the effect due to the tracing sequence by the first and second magnetic heads, minutely changing these parameters within a predetermined range and variably adjusting the equalizer parameters in a direction of reducing the signal error rate on the basis of the degree of the change of the signal error rate detected by the error rate detection unit.

Fig. 14 is a block diagram showing the construction of a reproducing system of a digital audio tape recorder according to the present invention.

The reproducing system, in which the present invention is applied to a reproducing apparatus which performs signal reproduction without tracking control as shown in Figs. 1 to 4, includes a rotational

magnetic head device having first and second rotational reproducing magnetic heads 2A, 2B mounted on a tape guide drum 2 at an angular interval of 180° from each other as shown in Fig. 2. Each of the magnetic heads has an azimuth angle corresponding to the recording azimuth of first and second inclined tracks TR_A, TR_B formed alternately on the magnetic tape 1 shown in Fig. 1. Each track of the magnetic tape 1, placed on the tape guide drum 2 over an angle of 180°, is traced completely only by being traced altemately by a plural number of times, such as twice, by the first and second rotational reproducing magnetic heads 2A, 2B.

The playback signals reproduced by the first and second rotational playback magnetic heads 2A, 2B are transmitted, as shown in Fig. 14, from a head changeover switch 3 via a playback amplifier to an analog-to-digital (A/D) converter 50. The A/D converter 50 converts the playback signal into binary signals and thereby into corresponding digital signals. The digital signals from the A/D converter 50 are supplied via an equalizer 54 to a data processor 52 which performs predetermined error correction and decoding operations on the digital signals supplied from the equalizer 54. In this manner, the digital processor 52 decodes the digital audio data from the digital signals to output decoded data as playback audio data at a signal output terminal 53.

In the above described reproducing system, the equalizer 54 constitutes an automatic equalizer 51, and is organized substantially as shown in Fig. 2. The equalizer 54 has its equalizer characteristics varied by three characteristic parameters C_1, C_2 and C_3 afforded from the characteristic parameter, control unit 55.

On the above described reproducing apparatus, the automatic equalizer 51 is constituted, as shown in Fig. 14, by the above mentioned equalizer 54 having its equalizer characteristics variable by the three characteristic parameters C_1, C_2 and C_3 afforded by the characteristic controlling unit 55, an error rate detection unit 56 for detecting the signal error rate ER of the output of the equalizer 54, a computing unit 57 for computing the extent of change of the signal error rate ER detected by the error rate detection unit 56, and a setting unit 58 for setting the characteristic parameters C_1 and C_2 of the equalizer 54, in a direction of diminishing the signal error rate ER, on the basis of the extent of change of the signal error rate ER computed by unit 57.

Of the parameter C_1, C_2 and C_3 afforded by the parameter control unit 55 to the equalizer 54, the third characteristic parameter C_3 is always fixed at a predetermined value, while the first and second parameters C_1 and C_2 are variably set in the automatic equalizer 51, so that optimum equalizer characteristics are afforded by the equalizer 54.

The characteristic parameter control unit 55 performs, in a two-dimensional plane that can be occupied by the characteristic parameters C_1 and C_2 afforded by the equalizer 54, a control operation, as shown in Fig. 15, of producing a minute orthogonal oscillation in the sequence of

$P_1(C_1, C_2)_{ODD}$
$\downarrow$
$P_2(C_1 + \Delta C_1, C_2)_{EVEN}$
$\downarrow$
$P_3(C_1 + \Delta C_1, C_2 + \Delta C_2)_{ODD}$
$\downarrow$
$P_4(C_1, C_2 + \Delta C_2)_{EVEN}$

that is, in the sequence in which the values of the characteristic parameters C_1 and C_2 are $P_1(C_1,C_2)_{ODD}$, $P_2(C_1+\Delta C_1,C_2)_{EVEN}$, $P_3(C + \Delta C_1,C_2+ \Delta C_2)_{ODD}$ and $P_4(C_1,C_2+ \Delta C_2)_{EVEN}$ for the first odd-number-ruple tracing, next even-number-ruple tracing, next odd-number-ruple tracing and the next even-number-ruple tracing, respectively.

The computing section 57 operates on the output of the equalizer 54 for the characteristic parameters having the values of $P_1(C_1,C_2)_{ODD}$, $P_2(C_1 + \Delta C_1,C_2)_{EVEN}$, $P_3(C_1 + \Delta C_1,C_2 + \Delta C_2)_{ODD}$, and $P_4(C_1,C_2 + \Delta C_2)_{EVEN}$ to compute the change ratio $\Delta ER/\Delta C_1$ of the variance ER of the error rate ER to the variance ΔC_1 of the first characteristic parameter C_1 from the signal error rates ER_1, ER_2, ER_3 and ER_4 detected by the error rate detection unit 56, in accordance with the equation (7).

$$\frac{\Delta ER}{\Delta C_1} = \frac{(ER_2 + ER_3) - (ER_4 + ER_1)}{2} \quad \cdots\cdots (7)$$

while computing the change ratio $\Delta ER/\Delta C_2$ of the variance ER of the error rate ER to the variance ΔC_2 of the second characteristic parameter C_2, in accordance with the equation (8)

$$\frac{\Delta ER}{\Delta C_2} = \frac{(ER_3 + ER_4) - (ER_1 + ER_2)}{2} \quad \text{.....} \quad (8)$$

In the above described reproducing apparatus, the characteristic parameter control unit 55 performs a control operation of allocating the characteristic parameters C_1 and C_2 applied to the equalizer 54, in the sequence not affected by the tracing sequence by the first and second rotational playback magnetic heads 2A, 2B, in an orthogonal relation as shown in Table 1, and minutely changing these parameters in a predetermined range to compute the change ratios $\Delta ER/\Delta C_1$ and $\Delta ER/\Delta C_2$ of the variance ΔER of the error rate ER to the variances ΔC_1, ΔC_2 of the characteristic parameters.

Table 1

Orthogonal Allocation for Two-Parameters				
	C_1	C_2	tracing	signal error rate
P_1	0	0	ODD	ER_1
P_2	1	0	EVEN	ER_2
P_3	1	1	ODD	ER_3
P_4	0	1	EVEN	ER_4

By allocating the cycle of the minute changes of the characteristic parameters C_1 and C_2 in an orthogonal relation as shown in Table 1, it becomes possible to compute at the unit 12 the ratios $\Delta ER/\Delta C_1$ and $\Delta ER/\Delta C_2$ of the variance ΔER of the error rate ER to the variances ΔC_1 and ΔC_2 of the parameters C_1 and C_2 by the equations (1) and (2) under the conditions less affected by the even-number-ruple tracing or odd-number-ruple tracing.

It is noted that the ratio $\Delta ER/\Delta C_1$ and $\Delta ER/\Delta C_2$ of the variance ΔER to the variances ΔC_1 and ΔC_2 of the characteristic parameters C_1 and C_2 can be computed in accordance with the equations (9) and (10).

$\Delta ER/\Delta C_1 = ER_2 - ER_1$ (9)

$\Delta ER/\Delta C_2 = ER_4 - ER_1$ (10)

without necessitating the signal error rate ER_3. However, by computing the rations $\Delta ER/\Delta C_1$ and $\Delta ER/\Delta C_2$ as mean values of each two measurements by the equations (1) and (2), using the signal error rates ER_1, ER_2, ER_3 and ER_4, it becomes possible to reduce the effects by the accidental errors as compared to the case of computing the ratios by the equations (9) and (10). Also, by employing the orthogonal allocation shown in Table 1, it becomes possible to offset the effects by the variances ΔC_2 and ΔC_1 when measuring the effect of the variances ΔC_1 and ΔC_2, respectively, so that the effect by the variances ΔC_1, ΔC_2 of the above characteristic parameters C_1 and C_2 can be detected highly accurately.

The data of the ratios $\Delta ER/\Delta C_1$ and $\Delta ER/\Delta C_2$ of the variance ΔER of the error rate ER to the variances ΔC_1,ΔC_2 of the parameters C_1, C_2, computed by the computing unit 57, are afforded to the setting unit 58.

On the basis of the ratio data $\Delta ER/\Delta C_1$, $\Delta ER/\Delta C_2$ of the variance ΔER of the error rate ER to the variances ΔC_1, ΔC_2 of the above mentioned characteristic parameters C_1 and C_2, the setting unit 58 sets the new values of the characteristic parameters C_1, C_2 in the following manner to diminish the error rate ER.

Thus the setting section 58 sets a new value of the first characteristic parameter C_1 to

$$C_1 + K \cdot \frac{\Delta ER}{\Delta C_1}$$

which is the value of the preceding first characteristic parameter C_1 added to by a correction value $K \cdot \Delta ER/\Delta C_1$. The setting section 58 also sets a new value of the second characteristic parameter C_2 to

$$C_2 + K \cdot \frac{\Delta ER}{\Delta C_2}$$

which is the value of the preceding second characteristic parameter C_2 added to by a correction value $K \cdot \Delta ER/\Delta C_2$. In the above formulae, K stands for a proportionality constant.

The setting operation of the new characteristic parameters C_1 and C_2 by the setting unit 58 need not necessarily be a linear operation, but may also be a nonlinear operation, if the error rate ER may thereby be reduced effectively.

The new characteristic parameters C_1 and C_2, thus set by the setting unit 58, are afforded to the control unit 55, which then repeatedly performs the control operation of minute orthogonal oscillation of these new characteristic parameters C_1 and C_2, as mentioned hereinabove.

In this manner, the characteristic parameter control unit 55 causes the characteristic parameters C_1 and C_2 of the equalizer 54 to be changed within a predetermined range and, on the basis of the extent of the variance ΔER of the signal error rate ER detected by the error rate detection unit 56, repeatedly performs an operation of variably controlling the characteristic parameters C_1 and C_2 of the equalizer 37 in the direction of diminishing the error rate ER for automatically controlling the characteristic parameters C_1 and C_2 of the equalizer 54 to the state of the minimum signal error rate ER.

In the above described embodiment, the characteristic parameters C_1 and C_2 of the equalizer 54 are changed to effect a control to optimum values. However, in the reproducing apparatus of the present invention, the number of the characteristic parameters of the equalizer to be changed need not be limited to two as in the present embodiment. For example, when three characteristic parameters C_1, C_2 and C_3 are to be changed, these parameters are allocated in an orthogonal relation as shown in Table 2 to measure the signal error rates ER_1, ER_2, ER_3 and ER_4.

Table 2

Orthogonal Allocation for Three Parameters				
	C_1	C_2	C_3	signal error rates
P_1	0	0	0	ER_1
P_2	1	0	1	ER_2
P_3	1	1	0	ER_3
P_4	0	1	1	ER_4

Then, the degrees of the effect $\Delta ER/\Delta C_1$ and $\Delta ER/\Delta C_2$ by the variances ΔC_1 and ΔC_2 of the characteristic parameters C_1 and C_2 may be computed from the above equations (7) and (8), while the degree of the effect $\Delta ER/\Delta C_3$ by the variances ΔC_3 of the characteristic parameter C_3 may be computed from an equation (11)

$$\frac{\Delta ER}{\Delta C_3} = \frac{(ER_2 + ER_4) - (ER_1 + ER_3)}{2} \quad \ldots\ldots (11)$$

When four to seven characteristic parameters are to be changed, these parameters are allocated in an orthogonal relation, as shown for example in Table 3, to compute the signal error rates ER_1, ER_2, ER_3, ER_4, ER_5, ER_6 and ER_7.

Table 3

Orthogonal Allocation for 4 to 7 Parameters								
	ΔC_1	ΔC_2	ΔC_3	ΔC_4	ΔC_5	ΔC_6	ΔC_7	signal error rate
P_1	0	0	0	0	0	0	0	ER_1
P_2	0	0	0	1	1	1	1	ER_2
P_3	0	1	1	0	0	1	1	ER_3
P_4	0	1	1	1	1	0	0	ER_4
P_5	1	0	1	0	1	0	1	ER_5
P_6	1	0	1	1	0	1	0	ER_6
P_7	1	1	0	0	1	1	0	ER_7
P_8	1	1	0	1	0	0	1	ER_8

On the basis of the measured results of the signal error rates ER_1, ER_2, ER_3, ER_4, ER_5, ER_6 and ER_7, the degrees of effect $\Delta ER/\Delta C_1$, $\Delta ER/\Delta C_2$, ... , $\Delta ER/\Delta C_7$ by the variances ΔC_1, ΔC_2, ... , ΔC_7 of the characteristic parameters C_1, C_2, ... , C_7 may be computed by the equations (12) to (18):

$$\frac{\Delta ER}{\Delta C_1} = \{(ER_5 + ER_6 + ER_7 + ER_8) - (ER_1 + ER_2 + ER_3 + ER_4)\} / 8 \qquad \ldots\ldots (12)$$

$$\frac{\Delta ER}{\Delta C_2} = \{(ER_2 + ER_4 + ER_7 + ER_8) - (ER_1 + ER_2 + ER_5 + ER_6)\} / 8 \qquad \ldots\ldots (13)$$

$$\frac{\Delta ER}{\Delta C_3} = \{(ER_3 + ER_4 + ER_5 + ER_6) - (ER_1 + ER_2 + ER_7 + ER_8)\} / 8 \qquad \ldots\ldots (14)$$

$$\frac{\Delta ER}{\Delta C_4} = \{(ER_2 + ER_4 + ER_6 + ER_8) - (ER_1 + ER_3 + ER_5 + ER_7)\} / 8 \qquad \ldots\ldots (15)$$

$$\frac{\Delta ER}{\Delta C_5} = \{(ER_2 + ER_4 + ER_5 + ER_7) - (ER_1 + ER_3 + ER_6 + ER_8)\} / 8 \qquad \ldots\ldots (16)$$

$$\frac{\Delta ER}{\Delta C_6} = \{(ER_2 + ER_3 + ER_6 + ER_7) - (ER_1 + ER_4 + ER_5 + ER_8)\} / 8 \qquad \ldots\ldots (17)$$

$$\frac{\Delta ER}{\Delta C_7} = \{(ER_2 + ER_3 + ER_5 + ER_8) - (ER_1 + ER_4 + ER_6 + ER_7)\} / 8 \qquad \ldots\ldots (18)$$

With the reproducing apparatus of the present invention, as described hereinabove, the characteristic parameter control means repeatedly performs a control operation of allocating the characteristic parameters of the equalizer in an orthogonal relation in a sequence not affected by the tracing sequence by the first and second rotational reproducing magnetic heads, minutely changing these parameters within a predetermined range and variably adjusting the characteristic parameters of the equalizer in the direction of diminishing the signal error rate on the basis of the changing degree of the signal error rate of the equalizer output detected by the error rate detecting means, whereby the change in the effect of the characteristic parameters of the equalizer during odd-number-ruple-tracing and even-number-ruple tracing may be efficiently extracted for efficiently and reliably converging the characteristic parameters to optimum values. The playback output from the first and second reproducing rotational magnetic heads are converted into binary signals, to which equalizer characteristics are afforded by the equalizer, and the equalized output from the equalizer is decoded by decoding means into digital signals, so that reproduced digital signals having a low signal error rate and superior quality may be produced by the decoding means.

Thus the present invention may provide a signal reproducing apparatus, which performs signal reproduction without tracking, with an automatic equalizing function, whereby the changes in the effect of the characteristic parameters of the equalizer during even-number-ruple tracing and odd-number-ruple tracing may be extracted efficiently, so that the overall system may be simplified in structure without increasing the weight, costs or power consumption.

Claims

1) An automatic equalizer comprising
an equalizer with variable parameters,
changing means for changing the parameters of said equalizer within a predetermined range,
detection means for detecting the error rates of an output of said equalizer
extracting means for extracting the degree of change in said error rate in said parameters changed by said changing means, and
setting means for setting parameters of said equalizer to reduce said error rate on the basis of the degree of change of the error rate extracted by said extracting means, and affording the set parameters to said changing means.

2) An automatic equalizer comprising
an equalizer having variable characteristic parameters,
error rate detection means for detecting the signal error rate of the output from said equalizer,
initial parameter setting means for sequentially detecting, at each of measurement points associated with preset plural characteristic parameters, the signal error rate of the equalizer output by said error rate detection means to find a minimum error rate measurement point to afford the thus found minimum error rate measurement point to said equalizer as an initial parameter, and
characteristic parameter control means for repeatedly performing a control operation of changing the characteristic parameters of the equalizer within a predetermined range and variably adjusting the characteristic parameters of the equalizer in the direction of diminishing the signal error rate on the basis of the degree of change of the signal error rate detected by said error rate detection means.
wherein the initial parameters are afforded to said equalizer by said initial parameter setting means for variably adjusting the characteristic parameters of said equalizer by said characteristic parameter control means.

3) The automatic equalizer according to claim 2 wherein said initial parameter setting means affords a measurement point with a signal error rate lower than a predetermined value to said equalizer as the initial parameter at the time point when said measurement point is detected.

4) The automatic equalizer according to claim 2 wherein, when the signal error rate of said equalizer exceeds a preset value of the signal error rate, said initial parameter setting means sets the initial parameter with the characteristic parameters in this state as one of said plural measurement points.

5) A signal reproducing apparatus in which each of first and second inclined tracks formed with different recording azimuths on a recording tape is traced alternately by first and second reproducing rotational magnetic heads having azimuth angles corresponding to the recording azimuth to reproduce digital signals, comprising
binary means for converting the reproduction output from said first and second reproducing rotational magnetic heads into binary signals,

an equalizer supplied with a binary output from said binary means and having variable characteristic parameters,
decoding means for decoding an equalized output supplied thereto from said binary means via said equalizer into a digital signal,
error rate detection means for detecting the signal error rate of a decoded output by said decoding means, and
characteristic parameter control means for repeatedly performing a control operation of allocating the characteristic parameters of said equalizer in an orthogonal relation in a sequence unaffected by the tracing sequence by said first and second rotational magnetic heads, changing the thus allocated characteristic parameters minutely within a predetermined range and variably controlling the characteristic parameters of said equalizer in the direction of diminishing said signal error rate on the basis of the degree of change of the signal error rate detected by said error rate detection means.

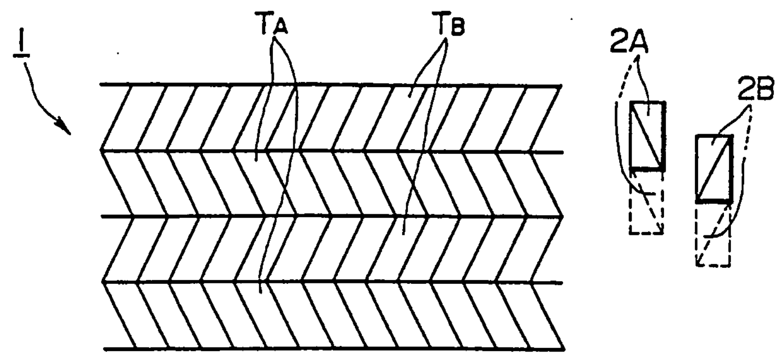


FIG.1

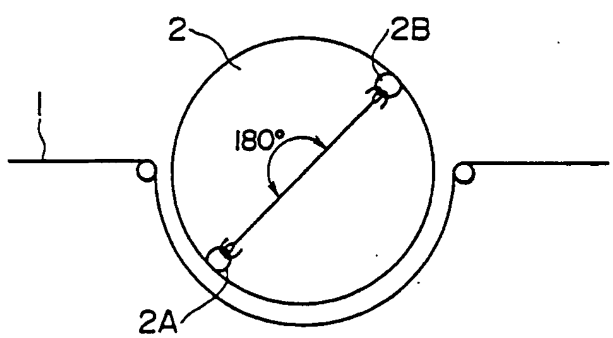


FIG.2

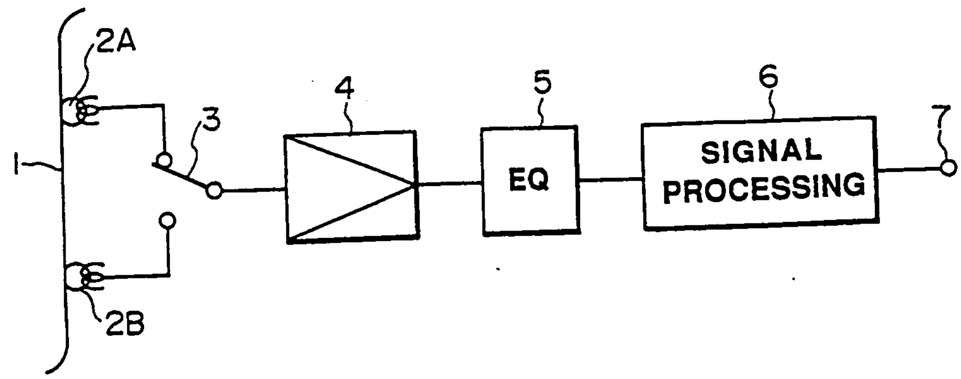

2A
3
4
5
6
7
1
EQ
SIGNAL
PROCESSING
2B

FIG. 3

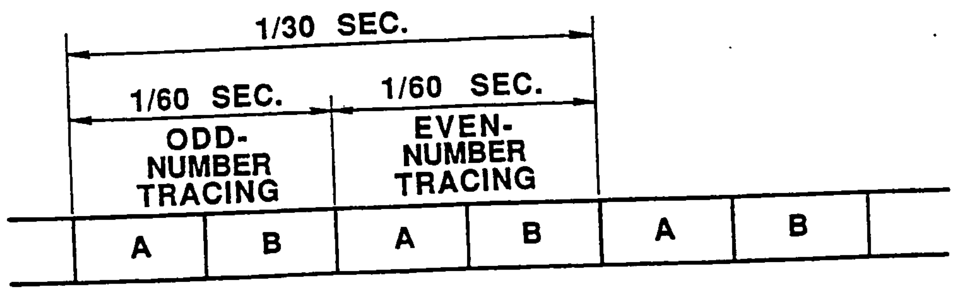
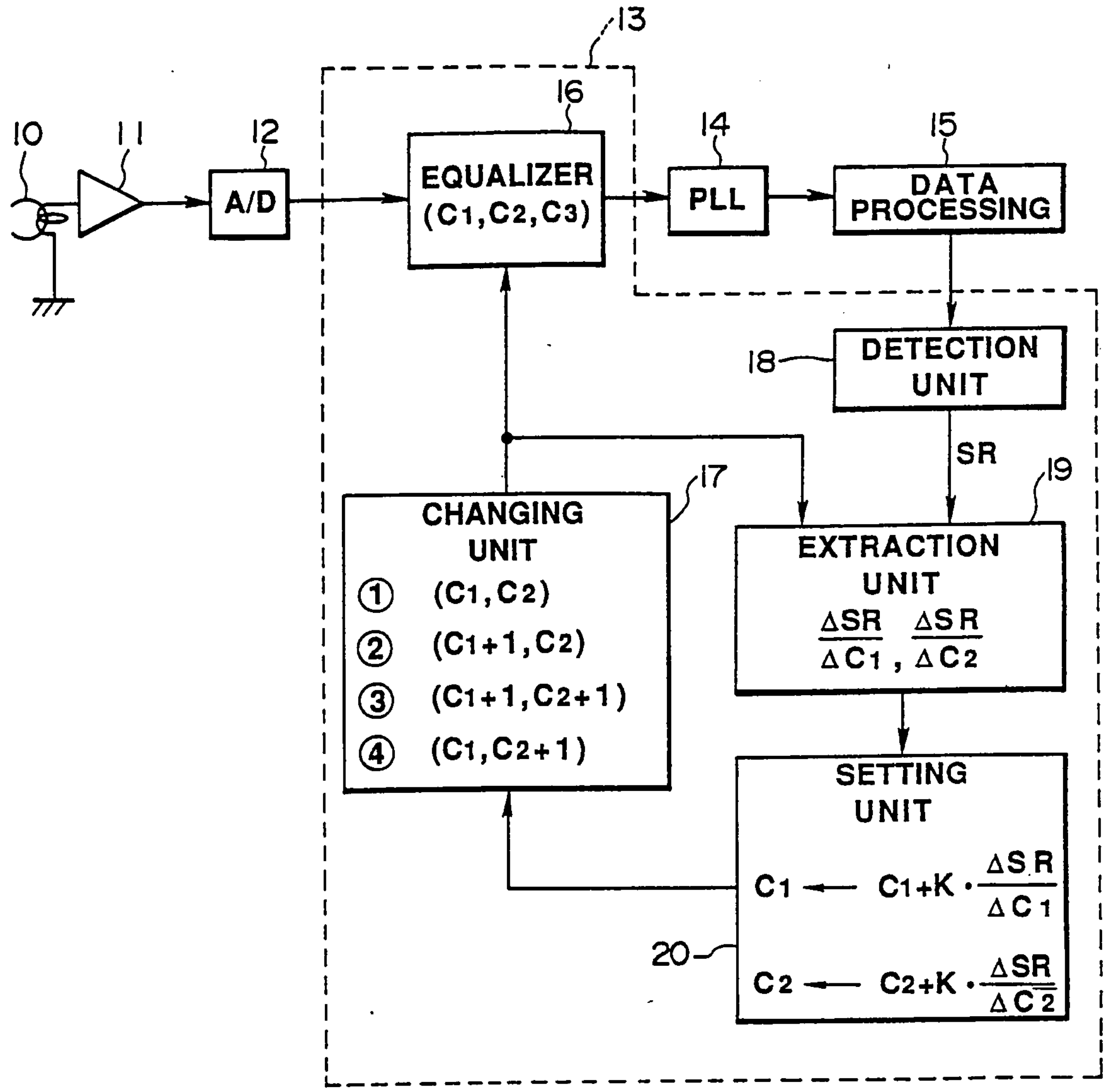

1/30 SEC.
1/60 SEC.
1/60 SEC.
ODD-
NUMBER
TRACING
EVEN-
NUMBER
TRACING
A
B
A
B
A
B

FIG. 4



13
16
10
11
12
14
15
A/D
EQUALIZER
(C1,C2,C3)
PLL
DATA PROCESSING
18
DETECTION UNIT
SR
19
17
CHANGING UNIT
① (C1,C2)
② (C1+1,C2)
③ (C1+1,C2+1)
④ (C1,C2+1)
EXTRACTION UNIT
ΔSR/ΔC1 , ΔSR/ΔC2
SETTING UNIT
C1 ← C1+K·ΔSR/ΔC1
20
C2 ← C2+K·ΔSR/ΔC2

FIG.5

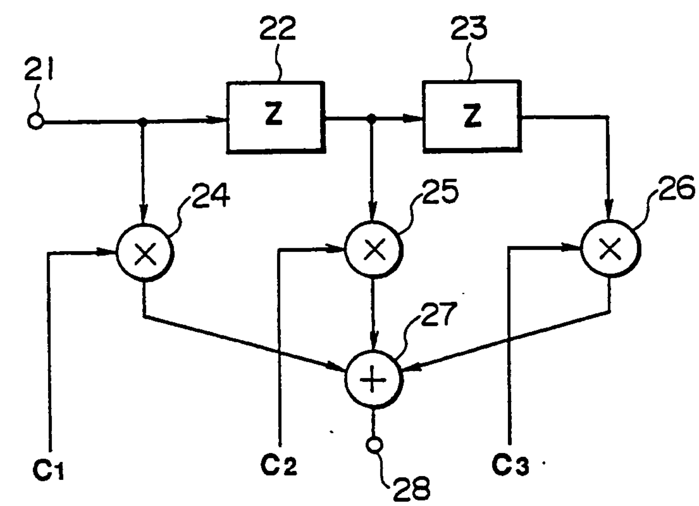

21
22
Z
23
Z
24
25
26
27
C1
C2
28
C3

FIG.6

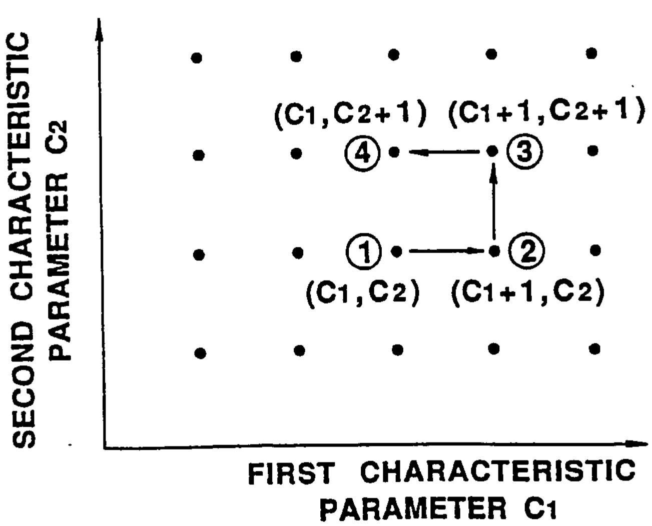

SECOND CHARACTERISTIC PARAMETER C2
(C1,C2+1)
(C1+1,C2+1)
4
3
1
2
(C1,C2)
(C1+1,C2)
FIRST CHARACTERISTIC PARAMETER C1

FIG.7

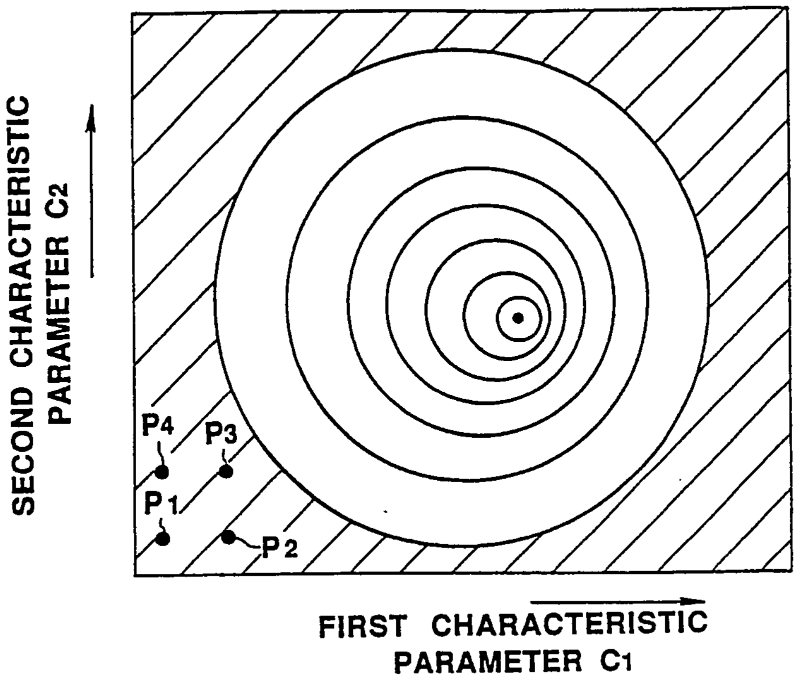

SECOND CHARACTERISTIC PARAMETER C2
P4
P3
P1
P2
FIRST CHARACTERISTIC PARAMETER C1

FIG.8

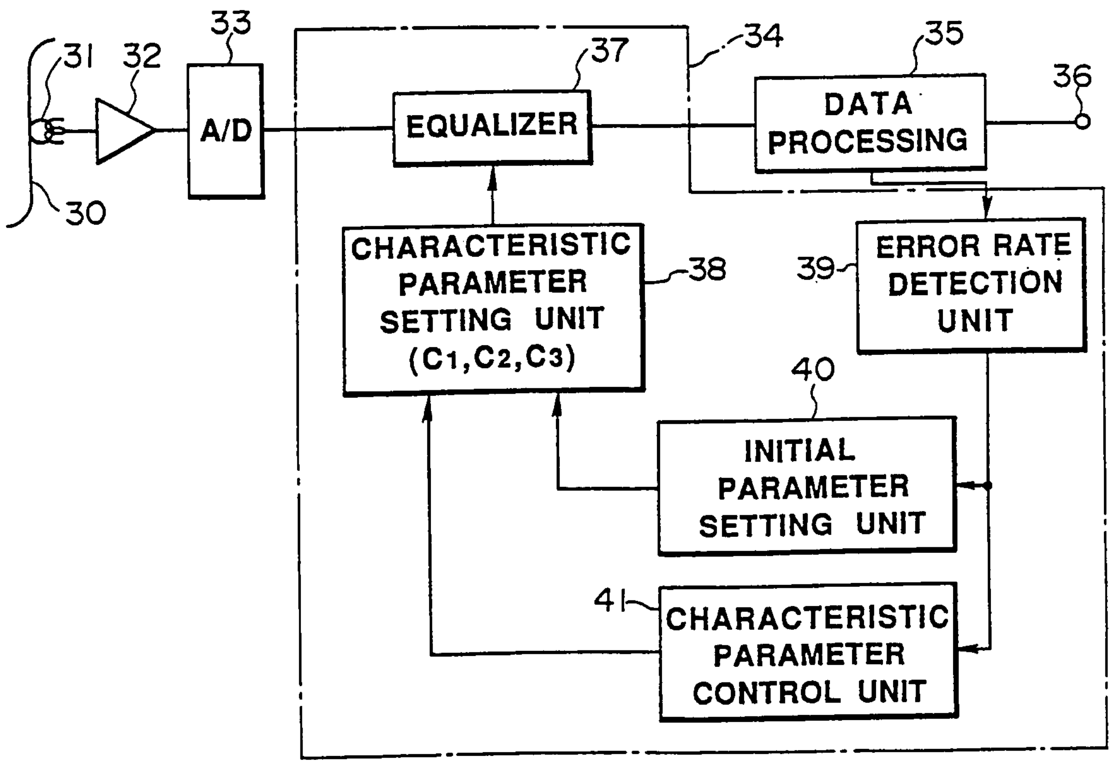

31
32
33
34
35
36
37
30
A/D
EQUALIZER
DATA PROCESSING
CHARACTERISTIC PARAMETER SETTING UNIT (C1,C2,C3)
38
39
ERROR RATE DETECTION UNIT
40
INITIAL PARAMETER SETTING UNIT
41
CHARACTERISTIC PARAMETER CONTROL UNIT

FIG.9

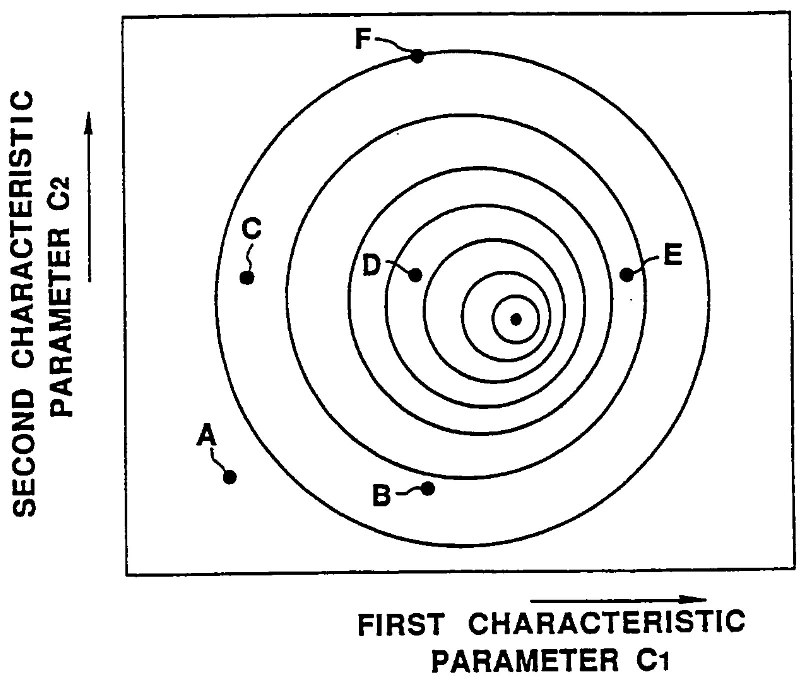

F
C
D
E
A
B
SECOND CHARACTERISTIC PARAMETER C2
FIRST CHARACTERISTIC PARAMETER C1

FIG.10

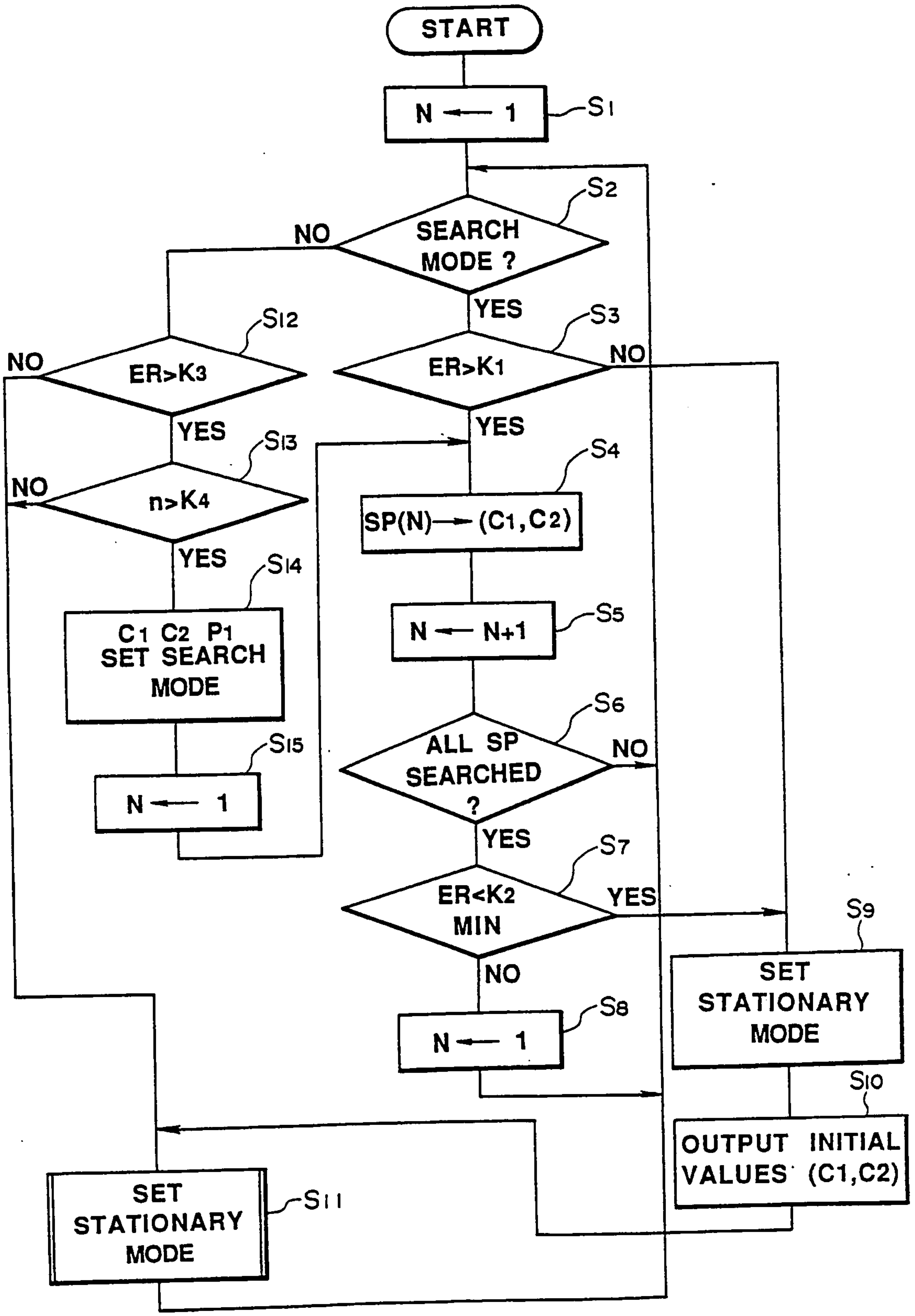

START
N ← 1
S1
SEARCH MODE ?
S2
NO
YES
ER>K1
S3
NO
YES
SP(N) → (C1,C2)
S4
N ← N+1
S5
ALL SP SEARCHED ?
S6
NO
YES
ER<K2 MIN
S7
YES
NO
N ← 1
S8
SET STATIONARY MODE
S9
OUTPUT INITIAL VALUES (C1,C2)
S10
ER>K3
S12
NO
YES
n>K4
S13
NO
YES
C1 C2 P1 SET SEARCH MODE
S14
N ← 1
S15
SET STATIONARY MODE
S11

FIG.11

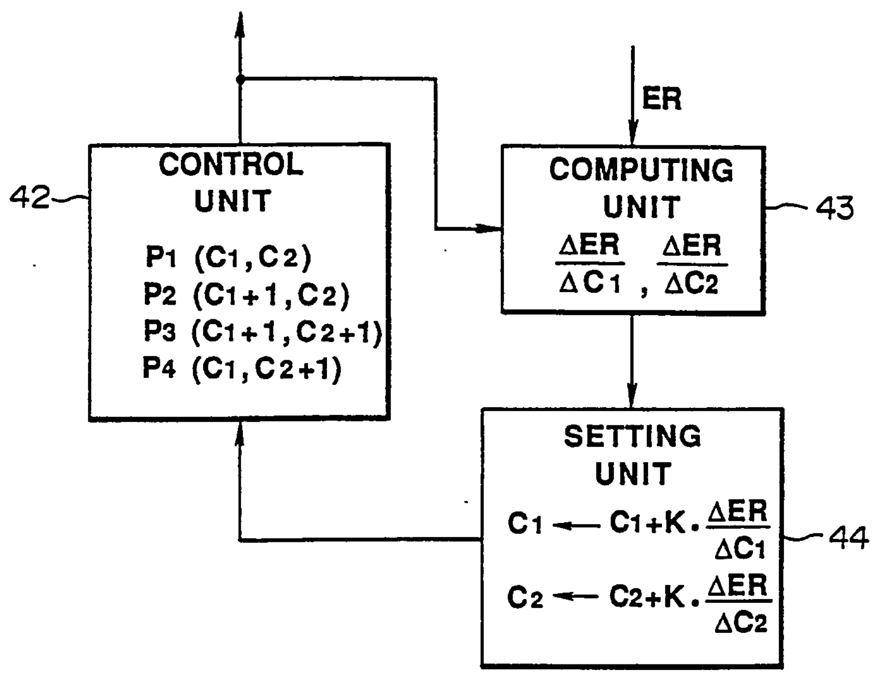

CONTROL UNIT
P1 (C1, C2)
P2 (C1+1, C2)
P3 (C1+1, C2+1)
P4 (C1, C2+1)
42
ER
COMPUTING UNIT
ΔER/ΔC1 , ΔER/ΔC2
43
SETTING UNIT
C1 ← C1+K.ΔER/ΔC1
C2 ← C2+K.ΔER/ΔC2
44

FIG.12

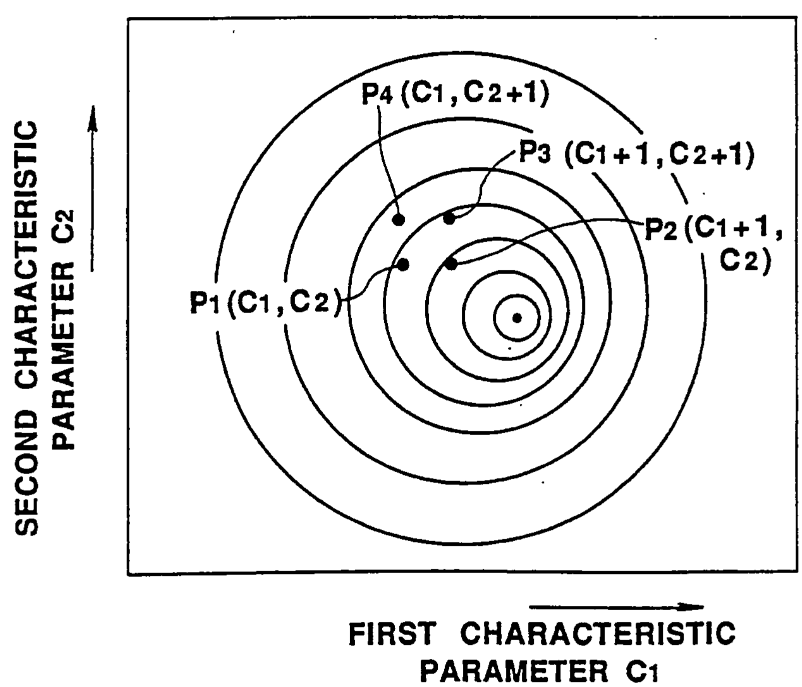

P4 (C1, C2+1)
P3 (C1+1, C2+1)
P2 (C1+1, C2)
P1 (C1, C2)
SECOND CHARACTERISTIC PARAMETER C2
FIRST CHARACTERISTIC PARAMETER C1

FIG.13

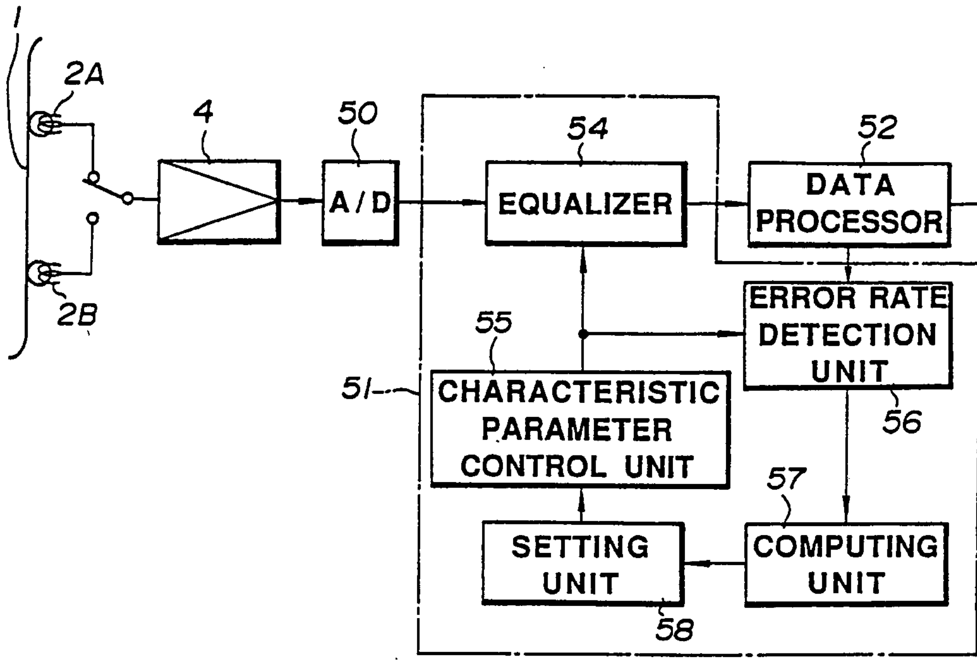

1
2A
2B
4
50
A/D
54
EQUALIZER
52
DATA PROCESSOR
53
55
51
CHARACTERISTIC PARAMETER CONTROL UNIT
ERROR RATE DETECTION UNIT
56
57
SETTING UNIT
COMPUTING UNIT
58

FIG.14

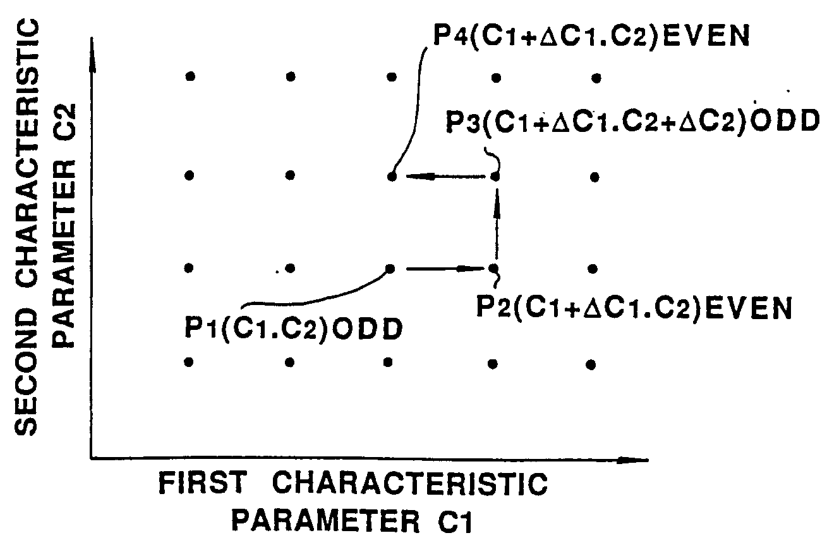

SECOND CHARACTERISTIC PARAMETER C2
P4(C1+ΔC1.C2)EVEN
P3(C1+ΔC1.C2+ΔC2)ODD
P1(C1.C2)ODD
P2(C1+ΔC1.C2)EVEN
FIRST CHARACTERISTIC PARAMETER C1

FIG.15